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Using Exploratory Factor Analysis to Build a Self-Efficacy Scale for Three-dimensional Modeling

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Abstract

Research on self-efficacy has provided evidence that it is a moderating factor that positively impacts students' choices to pursue and persist in engineering. Engineering graphics is seen as the preferred method of communication for the profession, yet to date no instrument is available that measures students' self-efficacy as it relates to engineering graphics. This paper discusses an exploratory factor analysis conducted to determine the reliability and validity of a self-efficacy scale designed specific to the domain of engineering graphics. Results from this study provided evidence that the instrument developed is reliable and valid for the investigation of students' self-efficacy as it relates to engineering graphics.

Introduction

Self-efficacy is rooted in Social Cognitive Theory, where theorists and researchers contend that knowledge acquisition directly relates to observing others within their context of social interactions, experiences, and outside media influences (Bandura, 1997). Research has provided evidence that self-efficacy beliefs in engineering disciplines significantly influences engineering students' choices to pursue and persist in engineering (Fantz, Siller, & Demiranda, 2011). Of particular interest in this study are students' self-efficacy beliefs towards engineering design graphics. Engineering graphics is a required area of study for many engineering programs and continues to be the preferred method for the communication of designs and ideas among engineering professionals (Barr, 2013; Branoff, Hartman, & Wiebe, 2002).

However, to date researchers have yet to create and validate a self-efficacy instrument related to engineering graphics. Research proffers that in order to be an adequate predictor of student performance, self-efficacy scales must be domain specific (Bandura, 2006). In this study, we examine the reliability, validity, and underlying factor structure of a self-efficacy scale specific to the domain of engineering graphics.
low-cost 3-D printers and new forms of modeling software to run them, the thought of universal graphicacy in society may already be happening.

Research Questions

The following questions guided this research:

RQ1. Is the domain-specific three-dimensional modeling self-efficacy scale reliable?

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RQ2. Is the domain-specific three-dimensional modeling self-efficacy scale valid?

RQ3. What is/are the underlying latent constructs for the items in the domain-specific three-dimensional modeling self-efficacy scale?

Methods

Instrument Development

Development of the three-dimensional modeling self-efficacy scale began with modifying and building upon instruments used in prior studies and grounded in the work of Bandura, especially his *Guide for Constructing Self-Efficacy Scales* (2006). The format of the instrument used in this study closely resembles the evaluation survey created by The New Traditions Project (Denson & Hill, 2010).

It was necessary to modify the scale items to relate specifically to the modeling of three-dimensional objects. Researchers collaborated with subject matter experts (SME) in graphics communication at a large land-grant institution to confirm the existing items were associated with engineering graphics. The SMEs provided comments and feedback, which the researchers incorporated into the scale design. The SMEs and researchers agreed that the resulting instrument measured the desired domain of three-dimensional modeling. In achieving face validity, the instrument provided evidence of measuring the constructs it purported to assess from the perspective of a participant (Weiner & Craighead, 2010). Figure 1 displays the nine-item three-dimensional modeling self-efficacy scale developed for, and used in, this study. Each item uses a seven-point Likert-type scale from “highest level of agreement” to “lowest level of agreement”.

1. I feel that I am good at visualizing/manipulating 3D objects in space.
2. I have confidence in my ability to model 3D objects using computers.
3. I am confident enough in my 3D modeling to help others model 3D objects.
4. I am good at finding creative ways to model 3D objects.
5. I believe I have the talent to do well in 3D modeling.
6. I feel comfortable using 3D modeling software.
7. I feel confident in my ability to create 3D objects in a variety of ways.
8. I feel I can communicate 3D objects to other peers.
9. I always understand what 3D images are trying to communicate.

Figure 1. The three-dimensional modeling self-efficacy scale.

ISSN: 1949-9167

Participants

This study was conducted during a STEM summer camp at a large, southeastern land-grant university. One hundred and one middle and high school students participating in the summer camp took the survey at the end of their weeklong experience. Researchers used the results of ninety-one of the student participants. Students whose answers were considered to be outliers were removed from the study. Examples include students who answered “7” or “1” for each item indicating that they did not read and discern each item.

Requirements for exploratory factor analysis

Prior to conducting the EFA, we evaluated the adequacy of the sample. There are varying opinions in the extant literature on the appropriate sample size required for EFA. There is general acceptance that 100 is the recommended minimum sample size, however, there is evidence that EFA can yield reliable results with a sample as low as 50 for measures of social constructs provided the number of factors is low (de Winter, Dodou, & Wieringa, 2009). The literature also contends that a ratio of respondents to variables should be 10:1 (Yong & Pearce, 2013). We believe the sample in this case (n = 91) is adequate when considering these factors.

Findings

Descriptive statistics and tests for normality (skewness and kurtosis) are displayed in Table 1. Stata 14 was used to analyze the data in this study (StataCorp, 2017).

Table 1
Descriptive statistics and tests for normality for the three-dimensional modeling self-efficacy scale

	M	SD	Skewness	Kurtosis	chi2	p-value
1	4.85	1.52	.01	.95	**6.60**	0.037
2	4.66	1.68	.29	.00	**11.73**	0.003
3	4.15	1.58	.57	.12	2.87	0.238
4	4.68	1.73	.35	.00	**8.54**	0.014
5	5.23	1.47	.00	.30	**9.54**	0.009
6	4.48	1.82	.43	.00	**11.02**	0.004
7	4.59	1.59	.10	.10	5.34	0.069
8	4.40	1.74	.11	.03	**6.55**	0.038
9	4.73	1.70	.01	.86	**7.05**	0.030

Note. Values in bold are significant at $p < .05$ level.

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Reliability

The reliability of the three-dimensional modeling self-efficacy scale was determined using Cronbach's alpha statistic to address our first research question. We determined the nine-item three-dimensional modeling self-efficacy scale to be reliable (α = .81) based on the threshold of .70 (Drost, 2011) with an average inter-item covariance of .87.

Exploratory Factor Analysis

Factorability

Toward investigating the underlying factor structure of the self-efficacy scale and addressing our third research question, we conducted an exploratory factor analysis. The initial step in EFA is to determine the adequacy of the sample. To accomplish this, we used three methods of analysis: examination of the correlation matrix, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett's test of sphericity. Table 2 displays the correlation matrix. Analysis of the correlations revealed that all nine items significantly correlated with at least one other item with a minimum coefficient of .30 (Burton & Mazerolle, 2011).

Table 2
Intercorrelations for Items in the 3D Modeling Self-Efficacy Scale

Item	1	2	3	4	5	6	7	8	9
1	–								
2	.38	–							
3	.33	.49	–						
4	.21	.20	.33	–					
5	.22	.22	.24	.39	–				
6	.37	.63	.40	.16	.32	–			
7	.41	.45	.43	.41	.41	.53	–		
8	.32	.27	.40	.40	.31	.23	.50	–	
9	.27	.07	.24	.30	.18	.07	.11	.39	–

Note. Coefficients in bold are significant at p < .05 level.

An examination of the Kaiser-Meyer-Olkin measure of sampling adequacy suggested the sample was adequate for factoring (KMO = .80) and Bartlett's test of sphericity was significant ($\chi 2$ (36) = 233.452, $p < .001$) indicating the sample was not an identity matrix.

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These two measures combined with the analysis of the correlation matrix, support our contention that the sample is factorable (Burton & Mazerolle, 2011).

Factor determination
Once the factorability of the sample was determined, an EFA was conducted to determine the number of factors underlying the three-dimensional modeling self-efficacy scale. The results of the EFA for the nine-item scale can be found in Table 3.

Table 3
Factor Loadings from Exploratory Factor Analysis: Uniqueness, Eigenvalues, and Percentages of Variance for the 3D Modeling Self-Efficacy Scale (9-Item)

	Factor loading			
Item	1	2	3	Communality
1	.54	-.03	.16	.33
2	.64	-.38	.11	.57
3	.62	-.03	.15	.43
4	.51	.34	-.13	.40
5	.49	.14	-.24	.32
6	.65	-.41	-.03	.59
7	.74	-.04	-.21	.61
8	.61	.32	.05	.48
9	.34	.39	.24	.33
Eigenvalue	3.05	.70	.23	
% of Variance		90.41	20.78	7.06

Using Kaiser's criterion, factors with eigenvalues greater the 1.00 were retained (Yong & Pearce, 2013). To confirm this method, we also examined the total variance explained. Factor one explains 90.41 percent of the variance in the sample; greater than our determination criteria of .75. Both methods suggest a single factor structure for the self-efficacy scale. The single factor solution is displayed in Table 4.

ISSN: 1949-9167

Table 4
Single Factor Loading from Exploratory Factor Analysis: Uniqueness, Eigenvalues, and Percentages of Variance for the 3D Modeling Self-Efficacy Scale (9-Item)

Item	Factor loading	Communality
1	.54	.29
2	.64	.41
3	.62	.39
4	.51	.26
5	.49	.24
6	.65	.42
7	.74	.55
8	.61	.37
9	.34	.11
Eigenvalue	3.05	
% of Variance	90.41	

Conclusion

The results of the EFA provided evidence that the nine-item scale was a valid and reliable measure of students' self-efficacy as it relates to three-dimensional modeling. In a final determination, analysis of the factor loadings of the scale items indicated that item nine had both a remarkably low factor loading and communality values. As a result, we examined the construction of the item and determined that structurally it was very different than the eight preceding items. This determination led to us removing the item in the final version of the instrument.

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